

Surgical treatment of comminuted mandibular fractures using a low-profile locking mandibular reconstruction plate system

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ABSTRACT

Objective: The treatment of comminuted mandibular fractures is challenging due to the severity of associated injuries and the need for a careful diagnosis with adequate treatment planning. Recently, open reduction and stable internal fixation (OR-IF) with a load-bearing reconstruction plate have been advocated for reliable clinical outcomes with minimal complications. This clinical prospective study evaluated OR-IF in the surgical management of comminuted mandibular fractures with a new low-profile, thin, mandibular locking reconstruction plate. **Materials and Methods:** We prospectively assessed OR-IF of comminuted mandibular fractures with a low-profile locking mandibular reconstruction plate in 12 patients (nine men, three women; mean age 32.2 [range 16-71] years) between April 2010 and December 2011. The clinical characteristics and associated clinical parameters of patients were evaluated over a minimum follow-up period of 12 months. **Results:** Traffic accidents caused 50% of the fractures, followed by falls (25%). Four patients (33.3%) had associated midfacial maxillofacial fractures, while five patients had other mandibular fractures. Seven patients (58.3%) needed emergency surgery, mostly for airway management. Anatomical reduction of the comminuted segments re-established the mandibular skeleton in stable occlusion with rigid IF via extraoral (33.3%), intraoral (50%), or combined (16.7%) approaches. Immediate functional recovery was achieved. Sound bone healing was confirmed in all patients, with no complications such as malocclusion, surgical site infection, or malunion with a mean follow-up of 16.3 (range 12-24) months. **Conclusions:** OR-IF using a low-profile reconstruction plate system is a reliable treatment for comminuted mandibular fractures, enabling immediate functional recovery with good clinical results.

Keywords: Mandibular comminuted fracture, mandibular reconstruction plate, maxillofacial trauma, open reduction and internal fixation

INTRODUCTION

Comminuted mandibular fractures result from a significant impact to a localized area of the oromandibular complex, in which the mandibular bone is splintered, crushed, pulverized, or broken into several pieces.^[1] Finn^[2] earlier defined comminution as the presence of multiple fracture lines creating many small pieces of bone in the same region of the mandible (i.e. the angle, body, ramus, or symphysis). After assessing and stabilizing any

life-threatening condition, careful clinical assessment of the oromandibular complex is essential.^[1-3]

Securing an airway is the first step in the management of such trauma because the mandibular skeletal framework maintains the upper airway, and severe bleeding, hematoma, and swelling can extend to the surrounding soft tissues.^[1,4] Care must be taken to diagnose malocclusion, maxillofacial and dental instability, lacerations, and fifth and seventh nerve injuries.^[2,3] Computed

tomography (CT) with three-dimensional reconstruction is required for treatment planning.

The aim of comminuted mandibular fracture treatment is to restore the patient's anatomy, oromandibular function, and esthetic appearance, enabling immediate reintegration into social activities.^[3,4] The treatment of these fractures has long been a challenge because of the high rates of complicating infection and nonunion, as first described by Kazanjian 70 years ago in his treatment of mandibular gunshot wounds.^[5,6] He thought that nonunion was due to inadequate immobilization of the fragments and subsequent infection, rather than to the initial loss of bone.^[5,6] Based on Kazanjian's reported experience, it was historically accepted that one should not open these fractures because of the risk of stripping the blood supply to the osseous fragments, resulting in sequestration and infection.^[1,3,5,6] Several treatment methods have been discussed, including closed reduction, external pin fixation, internal wire fixation, and, more recently, open reduction and internal stable fixation (OR-IF) using plates or screws.^[3,7,8]

During the last decade, OR-IF using plates or screws has been advocated for comminuted mandibular fractures.^[1,2] Spiessl, Prein and Kellman stressed two fundamental principles to obtain adequate rigid IF: The fixation needs to support the full functional load, and absolute stability of the fracture construct must be achieved.^[9,10] These principles are prerequisite for sound bone healing and low infection rates. In 10-year retrospective review of 198 comminuted mandibular fractures, Ellis *et al.* elaborated on these principles and found that OR-IF with a mandibular reconstruction bone plate, when possible, had the lowest complication rate.^[1]

Technically, the mandibular bone reconstruction plate system must be sufficiently strong to bear huge oromandibular functional loads, and is typically more than 2.5-2.8 mm thick. However, the thick profile needed for sound bone healing caused many complaints regarding sensation and the skeletal profile, especially in women and older patients.

In 2010, a low-profile, 2.0 mm-thick mandibular reconstruction plate system was made available commercially (AO, MatrixMANDIBLE reconstruction plate; Synthes, Paoli, PA, USA). This plate is stiff and has sufficient mechanical strength for use of reconstruction in comminuted mandibular fractures. This prospective clinical study evaluated the surgical management of comminuted mandibular fractures using this new system.

MATERIALS AND METHODS

This prospective study was conducted between April 2010 and December 2012 in the Division of Oral and Maxillofacial Surgery, Kagawa Prefectural Central Hospital, Takamatsu, Kagawa, Japan. All patients with maxillofacial trauma who presented to us between April 2010 and December 2011 were screened for possible inclusion in the present study.

The inclusion criteria were: Comminuted mandibular fracture as defined with the presence of multiple fracture lines resulting in many to multiple small segmental pieces within the same anatomical area of the mandible (i.e. angle, body, ramus, symphysis); injury < 2 weeks

prior; and agreement to present for follow-up visits for a minimum postoperative period of 12 months. The exclusion criteria were: Pathological fracture; an old fracture; a history of radiation treatment of the head-and-neck region; and noncompliance.

Finally, 12 patients (nine men, three women; mean age 32.2 years [range 16-71 years]) with comminuted mandibular fractures were prospectively registered between April 2010 and December 2011 [Table 1]. All patients underwent OR-IF surgery featuring placement of a low-profile (2.0 mm-thick), locking mandibular reconstruction plate in our hospital. For each patient, we recorded age, gender, the history and etiology of injury, the region and the extent of comminution, and associated maxillofacial injuries. Our trauma team, including physicians specializing in emergency and critical care, neurosurgeons, and orthopedic surgeons, treated all concomitant injuries.

Postoperative examination

Patients were seen at 2 weeks and 1, 3, and 6 months postoperatively for regular follow-up, and as necessary whenever a clinical symptom developed. Occlusion and the extent of bone healing were evaluated via X-ray and CT. Elements of postoperative morbidity were examined during follow-up [Table 1]. The surgical wound and oromandibular function were evaluated in detail, with the aid of plain X-rays or CT, at 1, 3, 6 and 12 months postoperatively.

Indices used to evaluate clinical outcomes were as follows: Signs/symptoms of infection, paresthesia along the length of the mandibular alveolar-mental nerve, soft tissue dehiscence with surgical scar formation (in patients treated using an extraoral approach), occlusion, temporomandibular joint (TMJ) mobility, and the range of mouth-opening. Radiological indices were as follows: Nonunion/mobility of segments, and plate/screw breakage or loosening.

All patients provided written informed consent. This prospective clinical study was approved by the Ethics Committee of Kagawa Prefectural Central Hospital, Kagawa, Japan.

Surgical technique

First, rigid fixation of the teeth and alveolar segments was obtained with metal arch bars tied to the remaining stable teeth, and maxillomandibular fixation (MMF) was established at centric occlusion before OR of the fractures, providing an occlusal reference. Although unsalvageable teeth were extracted, careful attention was paid to preserving unstable teeth that could be stably re-implanted in the alveolar sockets and ligated to the metal arch bars. An extraoral approach was used, considering the presence and position of facial lacerations, to extend the primary wound to provide minimal surgical access and expose all fractures for fixation [Figures 1 and 2]. In the presence of facial lacerations that were small or distant from the fractures, an intraoral or combined small laceration-based extraoral and intraoral approach was used [Figures 1 and 2]. All fracture sites were exposed before reducing and fixing the fragments. Minimal debridement of the fractured bone was performed to maintain as much bone bulk as possible and avoid bone grafting. The mandibular fractured small segments were then reduced and fixed with lag screws, 2.0 or 1.5 miniplates, and bioresorbable plates for simplification whenever possible, to increase the stability of

Table 1: Kanno, *et al.*

Age	Sex	Sites of comminuted mandibular fracture	Associated Maxillofacial fractures	Cause of trauma	OR-IF	Approach
20	M	Symphysis	Le Fort-II/I	Traffic accident	Emergent	Extraoral
34	M	Symphysis - Rt mandibular body		Stumble	Emergent	Intraoral + Extraoral
71	M	Symphysis		Fall	3 rd day	Extraoral
31	M	Symphysis - Rt mandibular body	Maxilla	Traffic accident	7 th day	Intraoral
16	M	Symphysis - Lt mandibular angle		Sport (hockey)	2 nd day	Intraoral + Extraoral
40	F	Rt mandibular body		Traffic accident	5 th day	Extraoral
38	M	Symphysis		Traffic accident	Emergent	Intraoral
18	M	Symphysis	Lt mandibular angle	Sport (softball)	Emergent	Intraoral
25	M	Symphysis	Rt mandibular angle, Rt zygoma-orbit	Traffic accident	Emergent	Intraoral
28	F	Symphysis - Rt mandibular body	Lt mandibular condyle	Fall	Emergent	Extraoral
37	F	Lt mandibular body	Rt mandibular body, Rt mandibular condyle	Fall	Emergent	Intraoral
28	M	Lt mandibular body	Le Fort-III/II/I, Rt mandibular condyle	Traffic accident	9 th day	Intraoral
32.2					2.1	

OR-IF=Open reduction and internal fixation; Rt=Right; Lt= Left

comminuted bone fragments, before applying the low-profile, 2.0 mm-thick MatrixMANDIBLE locking reconstruction plate for load-bearing. Such treatment is standard during surgery to repair comminuted mandibular fractures.^[1,3,4] The lingual periosteum was maintained when possible. The entire fracture was bridged with the reconstruction plate, which was adapted to the buccal cortex below the mandibular neurovascular canal, with three or four bicortical locking screws on either side of the fracture. Other midfacial maxillofacial fractures were treated after this mandibular framework was completed to provide a landmark for occlusal unit restoration. Condylar head fractures were treated after stabilizing the comminuted mandibular framework.

A final intraoperative check of occlusion and TMJ movement with intraoperative X-rays was compulsory. The tissues were closed meticulously, with the use of drains as indicated.

No MMF was performed after OR-IF in any patient, except for five cases with fractures of both the midface and mandible, and in those who suffered condylar head fractures that were not surgically treated although the patients required training on elastic control over 14 days postoperatively to stabilize the occlusion. The arch bars were left for 4 weeks to act as a tension band and enhance the stabilization of the occlusal segments and unstable re-implanted teeth.

Intravenous antibiotics (1.0 g cefazolin sodium/12 h) were administered on admission to the hospital and continued until the third postoperative day. A liquid diet was initiated on the first or second postoperative day, and soft diets were recommended to all patients for the next 4 weeks.

RESULTS

Injuries were caused by traffic accidents ($n = 6$; 50%), falls ($n = 3$; 25%), sports accidents ($n = 2$, hockey and soft ball;

16.7%) and fainting ($n = 1$; 8.3%). Most ($n = 9$; 75%) injuries were high-energy [Table 1].

The comminuted mandibular fractures could be classified into four types based on the extent and site of injury: Symphysis ($n = 5$; 41.7%), body ($n = 3$; 25%), symphysis extending to the body ($n = 3$; 25%), and symphysis extending to the angle ($n = 1$; 8.3%) [Table 1]. Seven patients (58.3%) suffered associated midfacial maxillofacial or mandibular fractures. At least one tooth was present in the comminuted region in all 12 patients. Although careful attention was paid to preserving unstable teeth that could be stably tied to the metal arch bars with re-implantation, two teeth were removed during surgery in two cases. In seven patients (58.3%), eight teeth in the comminuted region required root canal treatment at local dental clinics after removing the arch bars 4 weeks postoperatively.

The timing of surgical treatment varied [Table 1]. Emergency surgery was performed a mean of 2.1 days after hospital admission in seven patients (58.3%), mostly for hemostasis and airway management as the first step of trauma management. This surgery was required because of severe bleeding, hematoma and swelling extending to the surrounding soft tissues, and loss of the mandibular framework maintaining the upper airway, which caused a risk of obstruction and dyspnea [Figures 1 and 2].

Four patients (33.3%) underwent OR-IF using an extraoral approach alone via extraoral incisions extended from the primary laceration [Table 1]. Six patients (50%), including those with facial lacerations that were small or distant from the surgical site, underwent OR-IF with an intraoral approach alone. Two patients (16.7%) underwent a combined laceration-based extraoral and intraoral approach [Table 1].

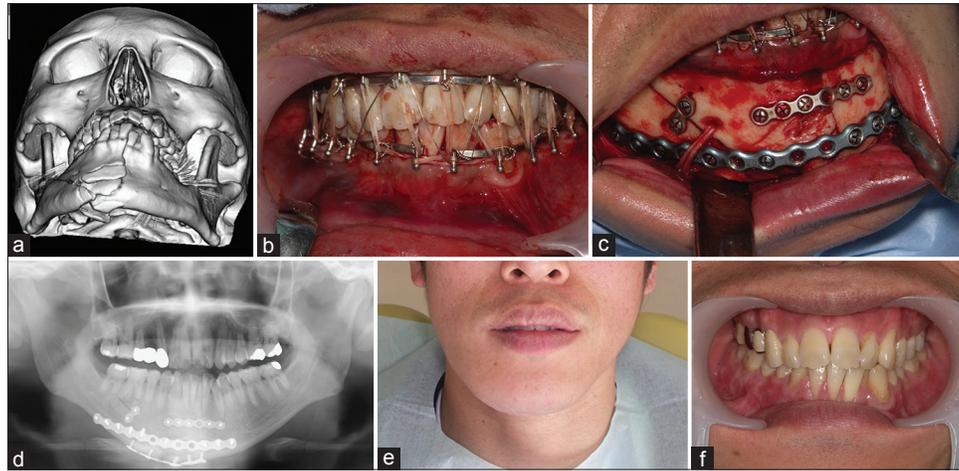


Figure 1: A 34-year-old man [patient no. 2, Table 1] suffered a comminuted fracture at the symphysis of the right mandibular body. (a) Preoperative three-dimensional computed tomographic images: Inferior view. (b) Metal arch bars were fixed to the remaining stable teeth and maxillomandibular fixation was established in centric occlusion before starting the open reduction and internal fixation (OR-IF). (c) After simplification of the comminuted fragments, the 2.0 mm-thick MatrixMANDIBLE reconstruction plate (Synthes, Paoli, PA, USA) for load-bearing was attached with bicortical locking screws. (d) Panoramic X-ray 3 months postoperatively. (e) Facial view 6 months postoperatively. (f) Intraoral view 6 months postoperatively

Postoperative complications

In all 12 patients, postoperative oral and occlusal rehabilitation, and facial form, were very good. Adequate OR-IF was achieved using the MatrixMANDIBLE reconstruction plate. No patient required any additional surgery.

No facial deformity, malocclusion, disocclusion, trismus, malunion, nonunion, surgical site infection, or osteomyelitis, was observed [Figures 1 and 2]. Notably, no signs of postoperative infection were noted in any patient. Preoperative neurological assessment revealed paresthesia along the length of the mandibular alveolar-mental nerve in eight patients (67%), and this remained immediately after surgery. Although patients were anxious about these symptoms, the symptomatic paresthesia decreased in extent and became partially resolved by 1 month, and continued to improve at the 3 and 6 months follow-ups. Three patients (25%) complained of continued neurological paresthesia at the sites of fracture, which, however, did not affect normal daily living, at the 12 months follow-up. Furthermore, scarring in patients treated via an extraoral approach (associated with lacerations) was minimal, and indeed almost invisible. No patient complained of any problem with the incision scar at 6 months postoperatively. In some patients, a reduced extent of mouth-opening and limitations in lateral excursion were noted for about 1 month postoperatively; active physical therapy was provided in the outpatient clinic. Upon such functional training, the range of mouth-opening improved gradually to 3 and also 6 months postoperatively, and the patients expressed satisfaction. At the 6 months follow-up, all 12 patients demonstrated satisfactory ranges of mouth-opening; all interincisal distances exceeded 40 mm, with stable individual centric occlusion. All patients had returned to consumption of a normal diet.

The mean duration of follow-up was 16.3 (range 12-24) months. No complication was observed either clinically or on X-rays, and no evidence of plate complications (plate/screw breakage or loosening) was apparent. Correct anatomical reduction of

comminuted segments re-established the mandibular form with stable occlusion accompanied by rigid IF, enabling immediate functional recovery and satisfactory re-integration into social life. Sound bone healing was confirmed in all patients [Figures 1 and 2].

DISCUSSION

In 10-year review of a large clinical sample, Ellis *et al.* found that OR-IF with a bone reconstruction plate had the lowest complication rate.^[1] In agreement with this finding, none of our recent cases treated with locking reconstruction bone plates developed malocclusion and all achieved favorable functional results with the 2.0 mm-thick system for the OR-IF of comminuted mandibular fractures. No facial deformity, malocclusion, disocclusion, trismus, malunion, nonunion, surgical site infection, or osteomyelitis developed after a mean follow-up period of 16.3 months. The MatrixMANDIBLE reconstruction plate is sufficiently strong for use in load-bearing situations in the mandible with bicortical screw fixation using at least three screws on either side of the comminuted region. This technique enables immediate oromandibular functional recovery with reintegration into social activities with no additional MMF.^[11,12]

However, these excellent clinical results might be related to the etiology of most comminuted mandibular fractures in Japan. In our study, the main cause of injuries was traffic accidents, followed by falls and sports accidents. No injury involved gunshots or explosives, which cause the most severe comminuted fractures and complications.^[1,7] This difference could be due to the strict laws governing privately owned firearms in Japan, which make gunshot wounds extremely uncommon. More severe comminuted mandibular fractures would require the use of 2.5-2.8 mm-thick mandibular reconstruction plates for load-bearing or other conventional treatment modalities, such as external pin fixation or closed reduction methods.^[1,3] This difference could result in a difference in the complication rate.

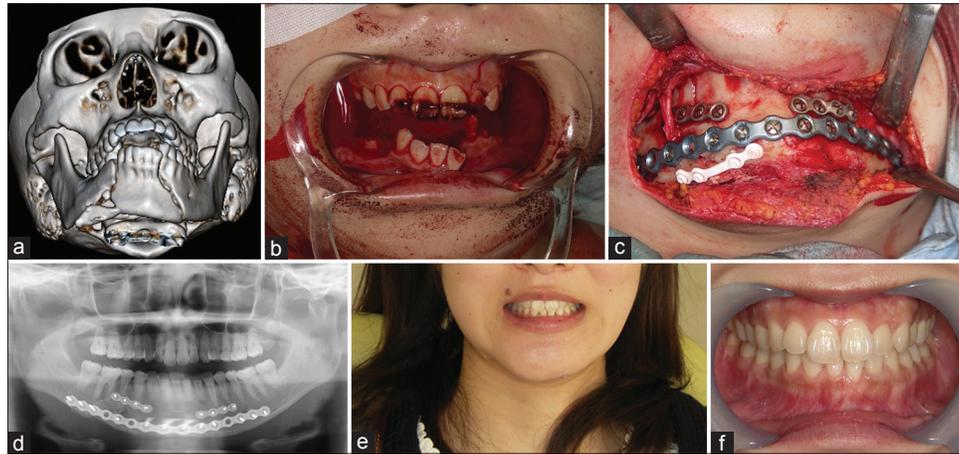


Figure 2: A 28-year-old woman [patient no. 10, Table 1] suffered a comminuted fracture at the symphysis of the right mandibular body. (a) Preoperative three-dimensional computed tomographic images: Inferior view. (b) Intraoral view showing the marked displacement of the symphyseal segment and severe intraoral bleeding. (c) After simplification of the comminuted fragments using miniplates and bioresorbable plates and maxillomandibular fixation in centric occlusion via an extraoral approach using a large laceration, the 2.0 mm-thick MatrixMANDIBLE reconstruction plate (Synthes, Paoli, PA, USA) was fixed with bicortical locking screws for load-bearing. (d) Panoramic X-ray 3 months postoperatively. (e) Facial view 6 months postoperatively. (f) Intraoral view 6 months postoperatively

Our clinical results are similar to those of a Chinese study, which involved similar social circumstances.^[13] Nevertheless, although Li and Li reported a low complication rate in their clinical review of 21 multiple comminuted mandibular fractures treated with stable rigid fixation using a large mandibular reconstruction plate, two patients (9.5%) developed surgical site infections and needed further surgery.^[13] Notably, one infection was caused by an untreated impacted tooth in the fracture line and most of the patients (76.2%) were treated late after initial treatment at other hospitals for bodily or craniocerebral injuries.^[13]

Unlike some previous reports, emergency treatment for comminuted mandibular fractures was necessary in seven patients (58.3%), with severe bodily or craniocerebral injuries, always in close consultation with neurosurgeons and orthopedic surgeons.^[3] As maxillofacial surgeons, we opted for emergency surgical treatment in tandem with orthopedic trauma surgeons treating multiple open fractures of the arms and legs. In these cases, after initial examination and critical emergency care, we first considered the loss of the mandibular skeletal framework maintaining the upper airway, and severe bleeding, hematoma, and swelling extending to the surrounding soft tissues. In most cases, our experienced anesthesiologists used emergency intubation to protect the airway, and the patient was transferred to the operating theater to manage the hemorrhage from the comminuted mandible first. Precise anatomical reduction of the comminuted segments reduces the risk of surgical site infection.^[14] In the other five patients (41.7%), the operation was delayed (range 1-9 days after the injury), similar to the results reported by Ellis et al.^[1,15] In these cases, we had to wait for the recovery of other injuries in consultation with other departments. Performing surgery on very fresh comminuted mandibular fractures likely enabled the good clinical results. Further, careful attention was paid to preserving unstable teeth that could be re-implanted stably in the alveolar sockets and tied to the metal arch bars, although unsalvageable teeth were extracted.^[3,16] Our tooth preservation rate was much higher than in previous reports, likely due to early surgical management with emergency OR-IF and more precise restoration of the occlusion with dental arch alignment, which reduced the

risk of postoperative infection.^[1,16,17] The involved teeth required root canal treatment after removing the arch bars and wires.

Occlusion is the best guide for the alignment of bony fragments, and must be established in the first stage of treatment of comminuted mandibular fractures or other midfacial maxillofacial fractures.^[17,18] Occlusal unit restoration could be a good treatment strategy for maxillofacial reduction before starting stable IF. An extraoral approach is recommended to obtain surgical access for complete OR-IF with a bone reconstruction plate;^[3] we extended the facial laceration at the fracture site in four patients (33.3%). We used an intraoral approach in six cases (50%), including those with facial lacerations that were small or distant from the surgical site. A combined small laceration-based extraoral and intraoral approach was used in two cases (16.7%). The new locking thin reconstruction plate might have contributed to the better handling than a conventional thicker plate, providing more surgical space affording good visualization and the ability to handle instruments comfortably during surgery to bridge the comminuted regions.^[18,19] The plate was well adapted to the buccal cortex below the mandibular neurovascular canal, with three or four bicortical locking screws placed on either side of the fracture for fixation.^[19] Furthermore, even with an intraoral approach, no postoperative complications occurred and immediate functional recovery was achieved, with nearly all patients tolerating a soft diet.

More than two decades have passed since the Arbeitsgemeinschaft für Osteosynthesefragen (Association for the Study of IF) group published information on the low incidence of major complications with OR-IF of comminuted mandibular fractures.^[3,9-11] Nearly a decade has passed since a large clinical review of the treatment of comminuted mandibular fractures elaborated on the utility of the mandibular reconstruction bone plate, updating information on the utility of the locking reconstruction plate with few complications.^[1,15] Here, we report a prospective clinical study demonstrating that the new thin locking reconstruction plate system yields good clinical results in the treatment of comminuted mandibular fractures. Furthermore, we recommend emergency

or early surgical management with OR-IF for these fractures to achieve immediate oromandibular restoration with occlusion and immediate reintegration into social activities.^[20]

CONCLUSION

OR-IF using a low-profile reconstruction plate system is a reliable treatment for comminuted mandibular fractures, enabling immediate functional recovery with good clinical results. The technique is safe, enabling stable sound bone healing with almost no clinical complications observed during a mean follow-up period of 16.3 months.

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